STRUCTURAL STYLES IN THE NANKAI ACCRETIONARY PRISM'S OUTER UNIT. AN INSIGHT INTO THE DEFORMATION MECHANISMS OF A YOUNG FOLD AND THRUST BELT

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Abstract. In this paper we intend to reveal the architecture and structural styles in the outer unit of the Nankai accretionary prism, using a 672 km^2 seismic survey that was acquired by the Japanese Government in 2006 in order to infer the origins of some major tsunamigenic earthquakes. Understanding deformation mechanisms and the distribution and morphology of the thrust sheets and faults is essential for the oil and gas industry and for academic study as well, as scientists intend to prevent the impact of devastating hazards that appear often in active tectonic settings, such as subduction zones.

Key words: Nankai, thrust, deformation, accretionary prism, tectonics

1. INTRODUCTION

We present in this project a view on the main deformation mechanisms that have been active in the Nankai accretionary prism for the last 2 Ma. The Nankai accretionary complex is a fold and thrust belt that has formed in response to the subduction of the Philippine Sea Plate beneath the Eurasian Plate, a tectonic process that commenced around 6 Ma, when convergence was initiated along Japan`s southern coast (Kimura *et al.*, 2005). It is marked by the accretion of a thick sedimentary succession that originates from the oceanic trench and the Shikoku back-arc basin (Park *et al.*, 2002).

Using a 3D seismic survey we were able to delineate major thrust sheets and faults in the region, in order to assess the structural styles and the architecture of the outer prism in the Nankai complex. Our interpretation shows that three deformation mechanisms exist in this area: fold bend fold, fold propagation fold and break thrust fault. Out of these three the most important is by far fault bend fold, which is present at a regional scale.

2. GEOLOGICAL SETTING

The Nankai accretionary prism is located near the southern coast of Japan, close to the Kii Peninsula (Fig. 1). It evolves as part of the Philippine Sea Plate – Eurasian Plate subduction system, in a tectonic cycle that started around 6 Ma, when tectonic convergence was reinitiated after a 8 Ma break (Kimura *et al.*, 2014). The Philippine Sea Plate moves north-westwards, beneath the Eurasian Plate, at a rate of 4 to 6.5 cm/year and an azimuth of 300º-315º (Miyazaki and Heki, 2001; Zang *et al.*, 2002; Seno *et al.*, 2002).

During the Miocene, convergence was active between the Eurasian Plate and the Pacific Plate in southern Japan, forming the Shimanto Belt, a fold and thrust belt formed in Cretaceous and Early Miocene times (Taira, 2001; Pickering *et al.*, 2013; Raimbourg *et al.*, 2014). Subduction was halted about 14 Ma, as it is shown by one last magmatic activity at about 15-13 Ma. The following tectonic stage lasted for 8 Ma and marked the north-eastward migration of the Boso triple junction, as the Philippine Sea Plate experienced senestral movements (Kimura *et al.*, 2005).

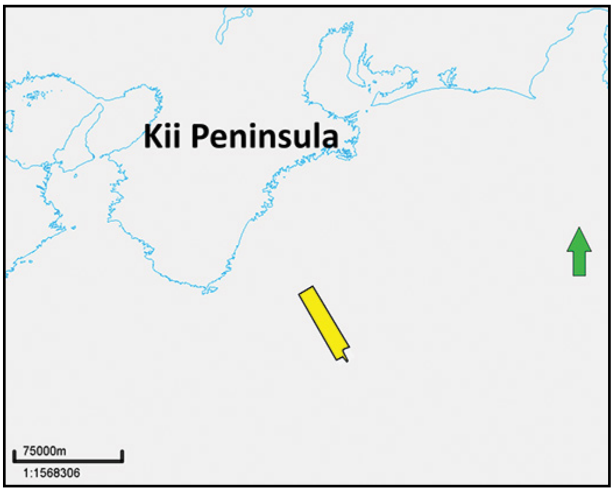

Fig. 1. Location of the study area and the seismic survey (the yellow polygon).

The Nankai fold and thrust belt formed through accretion of a thick sedimentary succession which consists of oceanic trench deposits and formations of the Shikoku back-arc basin (Park *et al.*, 2002). It is represented by two major units, the inner accretionary complex and the outer prism, which are separated by a transition zone that includes a major strike-slip thrust (Fig. 2) (Kimura *et al.*, 2007). The inner unit is a double-vergent accretionary system with highly deformed thrust sheets that hosts the Kumano Forearc Basin (Saffer *et al.*, 2009; Gulick *et al.*, 2010; Moore *et al.*, 2015). The outer unit is a young fold and thrust belt, formed in the last 2 Ma, which includes multiple thrust sheets which are arranged in an imbricate structure (Strasser *et al.*, 2009).

3. METHODOLOGY AND RESULTS

The seismic (PSTM) dataset for this study consists of a 672 km^2 survey that was acquired in 2006 by the JAMSTEC Agency in Japan as part of a scientific program which focused on the deformation mechanisms that trigger major earthquakes in the region. A seismic stratigraphy approach was used in the Kingdom 2017 software to map major structural elements (detachments, main thrust faults, representative reflectors that reveal the shape of the thrust sheets, in order to decipher the tectonic architecture and primary deformation mechanisms in the outer prism.

The first interpreted structural element was the Benioff Zone, which separates the Nankai accretionary complex, which is tectonically attached to the Eurasian Plate, from the subducting Philippine Sea Plate. The Benioff Zone dips to the north-west and acts as the main detachment surface in the region. It was observed that a secondary detachment, about 15 km long, parallel to the Benioff Zone, evolved in the outer unit of the accretionary prism, as a way to accommodate deformation in the early stages of tectonic development. The thrust faults in the frontal zone originate directly in the Benioff Zone, as the detachment extends to the oceanic trench, slowly incorporating its deposits (Fig. 3).

The thrust faults have been separated into two distinct categories: in sequence thrusts (IS) and out of sequence thrusts (OOST). OOST faults appear as reactivated, older, thrusts or represent younger rupture zones that start to form separate sheets (Fig. 3). The origin of these thrusts probably lies within periods of trench starvation, when the lower plate in the subduction system has a rugged morphology due to the presence of seamounts.

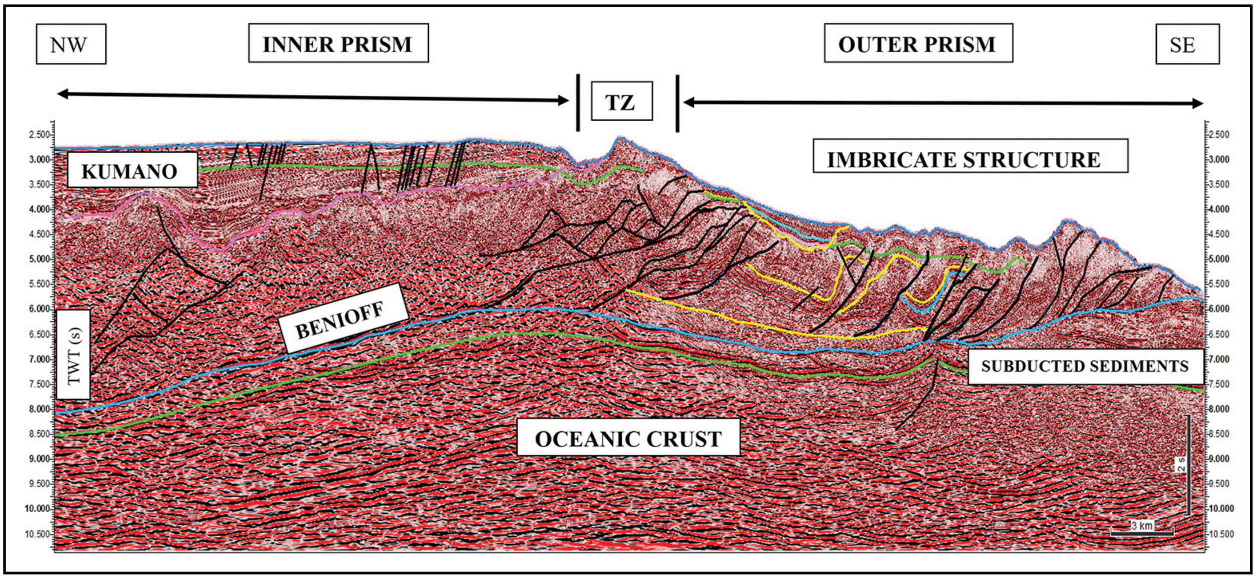

Fig. 2. Regional TWT seismic profile that illustrates the main tectonic units and elements in the region: Philippine Sea Plate, the inner complex, the transition zone (TZ), the outer prism, the Benioff Zone (main detachment), secondary detachment, thrust faults and sheets.

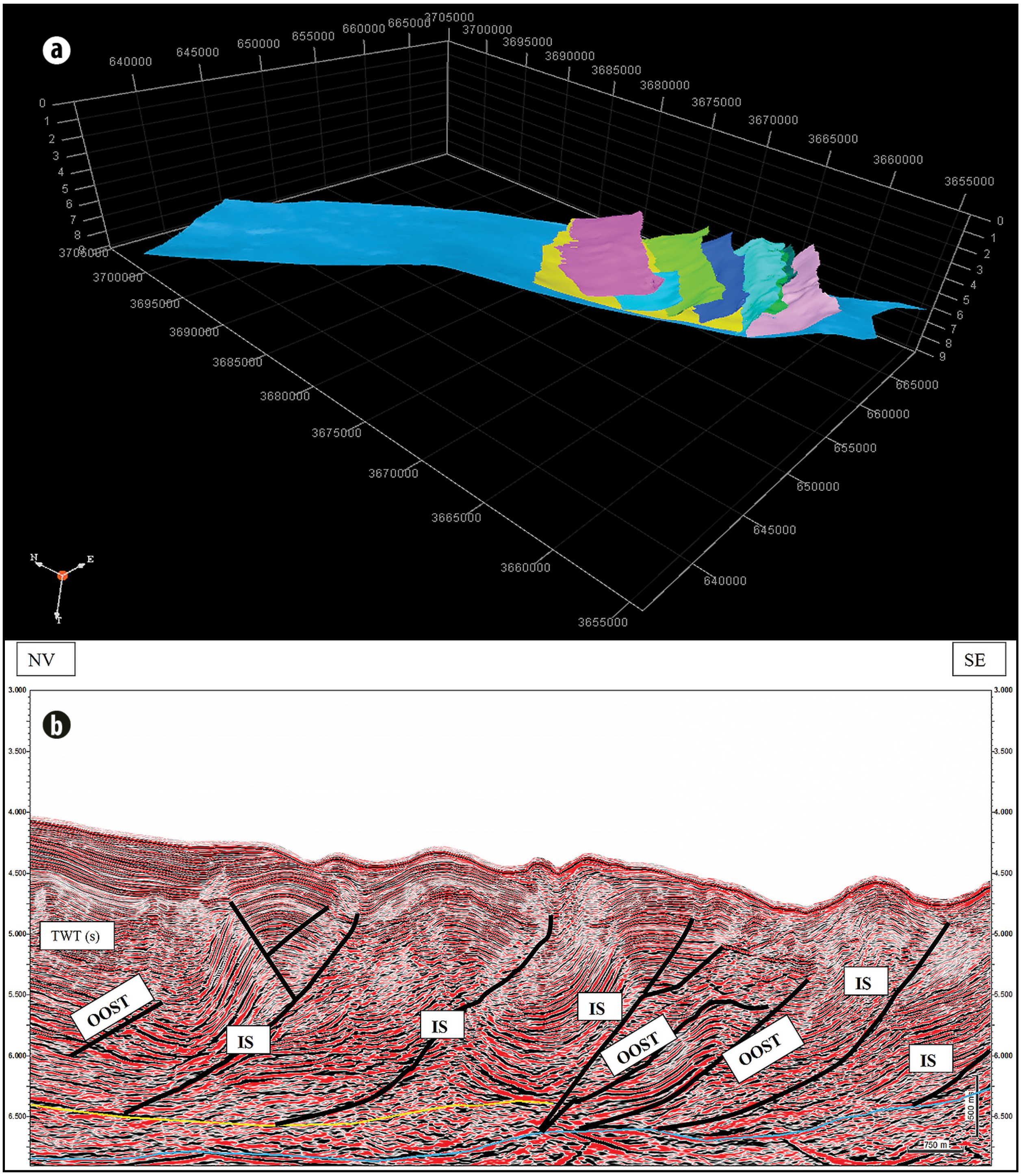

Fig. 3. 3D representation of the detachment surfaces and major thrusts in the outer prism (**a**). The seismic profile shows the two categories of thrust faults: in-sequence (IS) and out-of-sequence (**b**).

Based on the seismic sections observations and the structural maps it was noted that most thrust sheets in the region are oriented NE-SE and include an anticline-syncline pair that presents an elongated shape, as it should be expected from the geometry of a fold and thrust belt (Fig. 4).

In this area, three major deformation mechanisms have been active and led to the formation of the thrust sheets: fault bend fold, fault propagation fold and break thrust fold. Out of these three, the fault bend fold is the most common and essential deformation mechanism, being present in every thrust sheet of the outer accretionary prism (Fig. 5).

4. CONCLUSIONS

This study focused on the architecture and the deformation mechanisms in the outer unit of the Nankai accretionary prism, in the offshore area of southern Japan. It was observed that the fold and thrust belt includes two detachment surfaces: the Benioff Zone (main surface) and a secondary detachment that evolves on a distance of about 15 km. The outer prism consists of numerous sheets that have an elongated shape. These formed through three specific deformation mechanisms: fault bend fold, fault propagation fold and break thrust fold. The first one, fault bend fold, is very common, appearing in every thrust sheet in the accretionary complex.

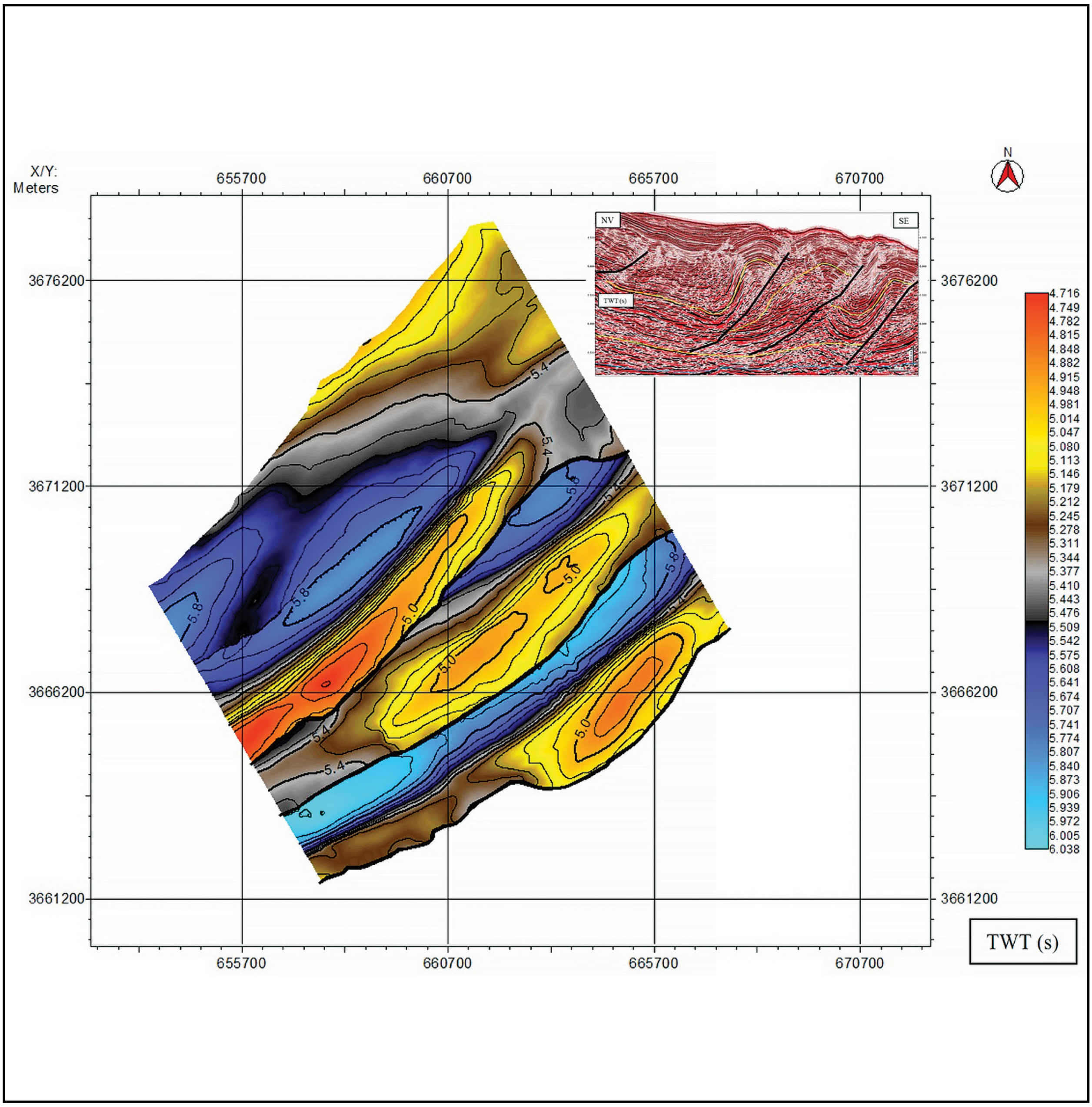

Fig. 4. Structural map for a representative seismic horizon mapped in three distinct thrust sheets that reveals the elongated shape of the anticlines.

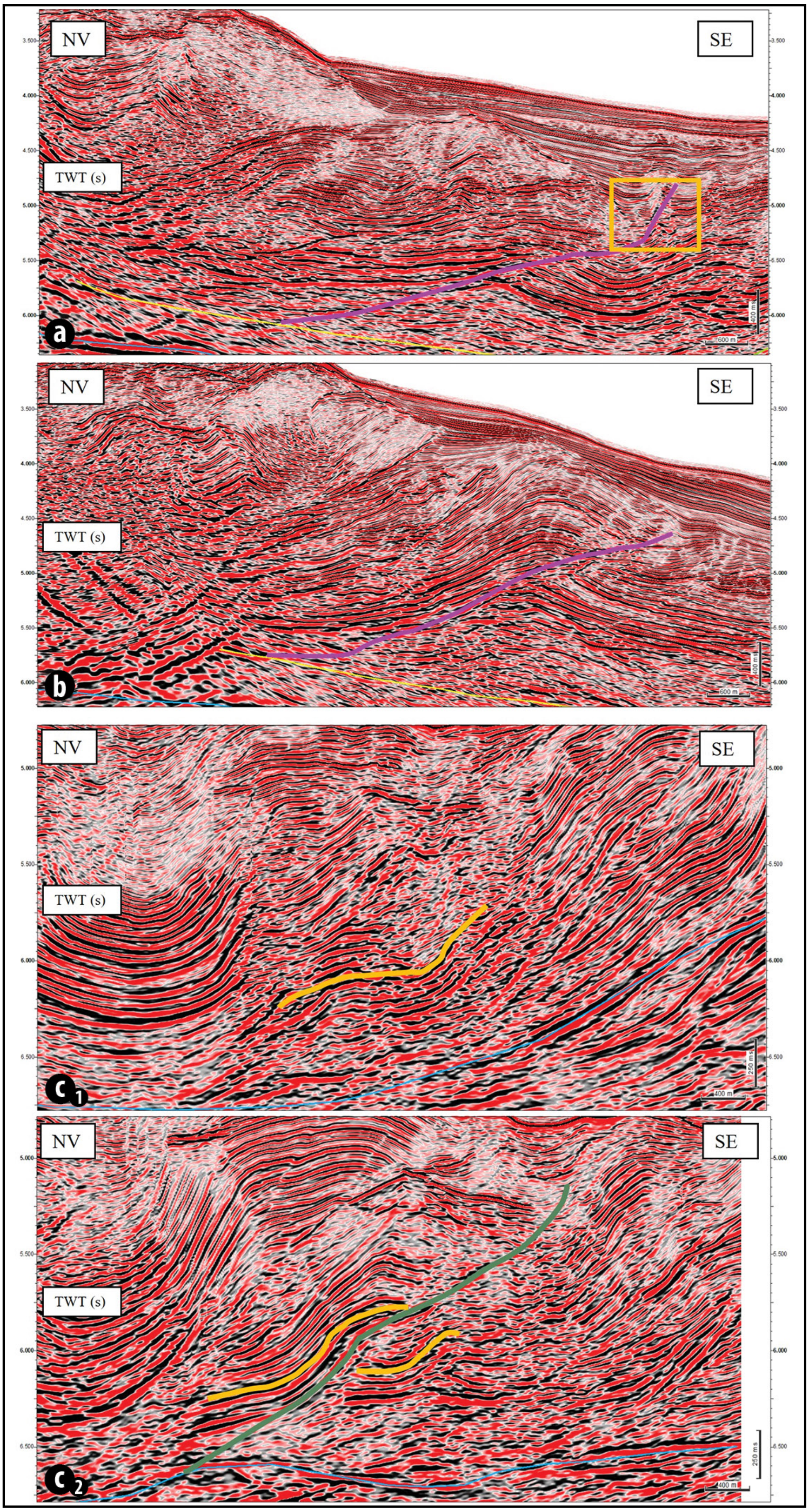

Fig. 5. Representative seismic profiles that evidentiate the deformation mechanisms: fold propagation fold (**a**), fold bend fold (**b**) and break thrust fold (**c**).

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